

CLAIMS:

1. An electric linear motor for driving a reciprocating load comprising:
a stator having a magnetically permeable core with at least one air gap and means for
5 producing a non constant magnetic flux in said stator and said at least one air gap;
an armature having a structure which supports at least one permanent magnet of which
at least a substantial portion is located in at least one of said at least one air gap, such that the
interaction of the magnetic field of said at least one permanent magnet and said non constant
flux in said at least one air gap producing a force on said armature, said armature in use being
10 connected to said load and thereby reciprocating with respect to said stator; and
energisation means for controlling said means for producing an alternating flux such
that at least one end of said at least one permanent magnet passes outside the region of
substantially uniform flux density present within said at least one of said at least one air gap
during a portion of the reciprocal motion of said armature.
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2. An electric linear motor as claimed in claim 1 wherein said means for producing an
alternating magnetic flux comprises at least one coil wound around a portion of said stator
and energised with a non constant voltage.
- 20 3. An electric linear motor as claimed in claim 2 wherein said energisation means
comprises a commutation circuit including a direct current power supply, switching devices
connected to said power supply to supply current to said at least one coil and a programmed
digital processor including memory and input-output ports, at least one of said ports being
connected to said commutation circuit to supply switching control signals thereto.
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4. An electric linear motor as claimed in claim 1 wherein the displacement of said at
least one permanent magnet at which said at least one end of said at least one magnet passes
outside said region of substantially uniform flux density is 67% of the maximum
displacement.
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5. A refrigerator which uses a compressor characterised in that the compressor and

compressor motor are linear devices and said motor comprises:

a stator having a magnetically permeable core with at least one air gap and means for producing a non constant magnetic flux in said stator and said at least one air gap;

an armature having a structure which supports at least one permanent magnet of which
5 at least a substantial portion is located in at least one of said at least one air gap, such that the interaction of the magnetic field of said at least one permanent magnet and said non constant flux in said at least one air gap producing a force on said armature, said armature in use being connected to said load and thereby reciprocating with respect to said stator; and

energisation means for controlling said means for producing an alternating flux such
10 that at least one end of said at least one permanent magnet passes outside the region of substantially uniform flux density present within said at least one of said at least one air gap during a portion of the reciprocal motion of said armature.

6. A vapour compressor comprising:

15 a piston,

a cylinder,

said piston being reciprocable within said cylinder, the vibrating system of piston, spring and the pressure of said vapour having a natural frequency which varies with vapour pressure,

20 a linear brushless DC motor drivably coupled to said piston having at least one winding,

a DC power supply,

commutation means for electronically commutating said at least one winding from
said DC supply to provide a supply of current to said at least one winding to reciprocate said
25 piston,

resonant driving means which initiate commutation of said at least one winding to thereby drive said piston at the resonant frequency of said vibrating system,

current controlling means which determine the amount of said supply of current supplied by said commutation means, said determined amount of current being related to
30 said resonant frequency, and which initiate commutation of said at least one winding to thereby limit the amplitude of reciprocation of said piston.

7. A vapour compressor as claimed in claim 6 further comprising:

a sensor for measuring a property of the vapour entering the compressor which is an indicator of the pressure,

and wherein said determined amount of current also being related to said measured

5 indicative property.

8. A vapour compressor as claimed in claim 7 wherein said sensor measures a property of the vapour entering the compressor which is an indicator of the pressure on evaporation.

10 9. A vapour compressor as claimed in any one of claims 6 to 8 wherein said resonant driving means comprising:

back EMF detection means for sampling the back EMF induced in said at least one winding when commutation current is not flowing and for detecting back EMF zero-crossings and producing timing signals derived therefrom, and

15 resonant commutation means which initiate commutation of said at least one winding in response to said zero crossing timing signals to thereby drive said piston at the resonant frequency of said vibrating system.

10. A vapour compressor as claimed in claim 9 further comprising

20 current detection means for measuring the current flowing in said at least one winding during commutation,

wherein said current controlling means terminates commutation when said measured current reaches said determined amount of current.

25 11. A vapour compressor as claimed in claim 10 wherein said commutation means includes switching devices connected to said DC power supply to supply current to said at least one winding and unidirectional current devices which supply a current path to dissipate energy stored in each winding after supply of current through a switching device has terminated, and said current detection means comprises:

30 a programmed digital processor including memory and input-output ports, a first port being connected to the output of said back EMF detection means and a second group of ports

being connected to said commutation means to supply switching control signals thereto,

software stored in said memory to cause said processor to determine a measure of motor current based on intervals between those zero crossings of said back EMF, which represent the duration of a current pulse produced in said at least one winding due to
5 dissipation of stored energy by said unidirectional current devices after supply of current has been removed from said at least one winding.

12. A vapour compressor as claimed in any one of claims 6 to 11 wherein said current controlling means further comprises:

10 means for measuring said resonant frequency,

a memory which stores at least one look up table containing maximum current commutation values for each of a plurality of resonant frequencies for said vibrating system, and

15 value selection means for selecting the value in said table which corresponds to said measured resonant frequency and for supplying same to said commutation controlling means.

13. A vapour compressor as claimed in either claims 7 or 8 wherein said current controlling means further comprising:

means for measuring said resonant frequency,

20 a memory which stores a plurality of look up tables stored in said memory containing maximum current commutation values for each of a plurality of resonant frequencies for said vibrating system, each look up table corresponding to a non-overlapping range of said indicative property, and

25 table selection means for selecting a look up table to use on the basis of the measured value of said indicative property,

value selection means for selecting the value in said table which corresponds to said measured resonant frequency and for supplying same to said commutation controlling means.

14. A vapour compressor as claimed in any one of claims 6 to 11 wherein said current
30 controlling means includes a processor storing instructions which when executed calculate said determined amount of current based on a mathematically expressible relationship to at

least said measured resonant frequency and optionally said measured indicative property.

15. A method for driving and controlling the amplitude of the piston in a free piston vapour compressor wherein said piston reciprocates in a cylinder and wherein the vibrating
5 system of piston, spring and the pressure of said vapour has a resonant frequency which varies with vapour pressure, said method using a linear brushless DC motor having at least one winding and comprising the steps of:

electronically commutating said at least one winding from a DC supply to reciprocate
said piston, with commutations timed to drive said piston at the resonant frequency of said
10 vibrating system, limiting the amount of current in said at least one winding by limiting the value of a parameter which determines current supply during commutation to a value which is a function of said resonant frequency.

16. A method as claimed in claim 15 further comprising the step of measuring a property
15 of the vapour entering the compressor which is an indicator of the pressure, wherein said selected maximum current commutation value is also a function of said measured indicative property.

17. A method as claimed in claim 16 wherein said measured indicative property is an
20 indicator of the pressure on evaporation.

18. A method as claimed in any one of claims 15 to 17 wherein said step of driving said piston at the resonant frequency of said vibrating system comprises the steps of:

unpowering said at least one winding at various intervals and detecting zero-crossings
25 of the back EMF induced in said at least one winding, using the zero-crossing timing information to initiate commutation of said at least one winding to thereby drive said piston at the resonant frequency of said vibrating system.

19. A method as claimed in claim 18 wherein said step of electronic commutation
30 comprises using commutation means includes switching devices connected to said DC power supply to supply current to said at least one winding and unidirectional current devices which

supply a current path to dissipate energy stored in each winding after supply of current through a switching device has terminated, measuring motor current based on intervals between those zero crossings of said back EMF, which represent the duration of a current pulse produced in said at least one winding due to dissipation of stored energy by said
5 unidirectional current devices after supply of current has been removed from said at least one winding, and terminating commutation when said measured current reaches said determined amount of current.

20. A method as claimed in either claims 16 or 17 further comprising a step of measuring
10 a property of the vapour entering the compressor which is an indicator of the pressure on evaporation, wherein said maximum current commutation value is selected from one of a set of look up tables containing maximum current commutation values for each of a plurality of resonant frequencies for said vibrating system and selecting the value which corresponds to the measured resonant frequency, each look up table corresponding to a non-overlapping
15 range of said indicative property and being selected on the basis of the measured value of said indicative property.

21. A method according to claim 20 wherein said parameter which is limited is the magnitude of the current and said look up tables store maximum current values.

22. A method according to claim 20 wherein parameter which is limited is the duration of commutation and said look up tables store maximum commutation duration values.

23. A vapour compressor according to claim 6 wherein instead of said piston and said
25 cylinder said compressor is a diaphragm type compressor.

24. A method according to claim 15 wherein instead of said piston and said cylinder said compressor is a diaphragm type compressor.